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BUREAU OF ENTOMOLOGY

FOREST INSECT INVESTIGATIONS

FURTHER STUDIES ON THE HEMLOCK LOOPER IN SOUTHWESTERN WASHINGTON

BUREAU OF ENTOMOLOGY
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Portland, Oregon
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INTRODUCTION

The hemlock looper is one of the most important forest defoliators found in the Pacific Northwest region. Its most serious depredations have been reported from the coast fog belt of Oregon, Washington and British Columbia although it has recently been found defoliating timber on the western slopes of the Cascade range up to elevations of fifteen hundred feet.

In the past forty five years, three major outbreaks have been reported on the coast of Oregon and Washington. The earliest outbreak of which there is any record occurred between 1889 and 1891 and destroyed an inestimable amount of timber in Tillamook and Clatsop Counties in Oregon and in Greys Harbor County in Washington. The second outbreak occurred in 1918-1921 in Tillamook County, Oregon. This epidemic is reported to have killed 500,000,000 board feet of hemlock and fir. The third and most recent outbreak of major importance occurred in 1928-1932 in Pacific County, Washington and according to Keen[1] had destroyed 162,000 M board feet by the end of 1931.

Reports of these early outbreaks indicate that they were of short duration usually lasting over a period of from three to five years and then subsiding as a result of natural control agencies.

[1] Report of the Hemlock Looper Outbreak in Southwestern Washington and Its Control Through Airplane Dusting. Report Dec. 10, 1931.

Because of the destructive character of past outbreaks the report of a new looper infestation in 1931 in Grays Harbor County, some fifty miles north of the older looper infested area in Pacific County, was received with considerable alarm. In November 1931, Buckhorn visited parts of the area in company with F. L. Nethery of the Weyerhaeuser Timber Company and E. Hobi of the Hobi Logging Company. A few moths were in flight and the damage was found to be due to defoliation by the hemlock looper. The area was again examined in the spring of 1932 by Keen and Beal when the insects were in the egg stage and again after the eggs began hatching.

The demand for information concerning the extent and severity of the new outbreak and the urgent request of private timber companies and local civic organizations that steps be taken to combat the infestation resulted in the assignment of the writer to make a study of the looper situation in Grays Harbor County. Work on this project began about the middle of June 1932 when the small looper larvae were present in large numbers and continued until mid-November, the end of the moth flight.

During the looper studies of 1931 a great deal of information was obtained on the life history and habits of this insect and this has already been fully presented by Keen[1]. There was a need for more detailed information on certain life history phases such as, length of various stages, number of larval instars, and observations on the moth flight, as well as a need for information con-

cerning the parasitic and predacious enemies of the looper. An attempt was made to obtain some of this essential information during the summer of 1932 in Grays Harbor and Pacific Counties. Only the additional information secured will be presented in this report.

THE AREA AFFECTED

The area of looper infested timber in the most recently reported outbreak lies in Grays Harbor County between Willapa Bay and Grays Harbor (Townships 15, 16 and 17 North, Ranges 8, 9 and 10 West). The country is not mountainous but the low hills, deep ravines and impenetrable underbrush make it a very difficult country in which to work. The area is covered with a dense stand of timber consisting chiefly of an overstory of hemlock, spruce and fir and a dense growth of underbrush of salal, huckleberry, etc. A few old logging roads penetrate into parts of the area but there are no lookout points, so that a view of the infested timber can be had only from the air.

The timber is largely a hemlock stand, the more valuable species having been heavily culled. Sitka spruce, Douglas fir and western red cedar have been much in demand and as a result these species make up a much smaller portion of the stand than formerly. Hemlock comprises about 65 per cent of the stand with Sitka spruce 20 per cent and Douglas fir and western red cedar 10 and 5 per cent respectively. Under the present economic conditions, it is useless to place values on the different tree species involved for just now there is a very limited market for any of it. However, the hemlock in this region is looked upon as a source of supply for large

pulp mills in Grays Harbor vicinity. The other species normally have high values for export trade or the more specialized wood using industries, or for construction purposes.

DISTRIBUTION

The hemlock looper is probably distributed throughout a large part of the coast fog belt type particularly in Oregon, Washington and British Columbia, and occasionally extends its work to the western slopes of the Cascade Range. For the first time a looper outbreak was found in 1932 in an area of hemlock and fir outside the coast fog belt type (map). A small outbreak of about a hundred acres extent was reported and examined at Darrington, Washington at an elevation of twelve to fourteen hundred feet. During the flight period, moths were found in two new areas within the coast fog belt. A few moths were seen in flight on the Olympic National Forest in the vicinity of Quinault Lake and more were seen further north on the forest just south of Crescent Lake. In talking with R. D. Maclay formerly of the Olympic National Forest, he reported seeing patches of dead timber on the Olympic while on airplane fire patrol duty during 1931. He attributed these patches of dead and dying timber to defoliation by the hemlock looper.

LIFE HISTORY AND HABITS

Further observations on life history and habits of the hemlock looper have added something to the knowledge obtained during previous years. The time of appearance of certain stages as well as their duration was secured in some cases (graph I).

The overwintering eggs in the field had largely hatched by the middle of June. The fact that at this time most of the larvae were already in the second instar indicated that they probably hatched during the preceding month. The larvae were found to pass through five larval instars during the period of growth and development; however, these are discussed elsewhere in detail under a special heading. The larvae apparently do not show very much ability in searching for new food. After eating off the needles from a particular branch they let themselves down to new foliage. In this way many of them reach the ground after which they climb trees, stumps, snags or anything in their path and once up these they show little or no inclination to come back down. In such situations many of them apparently starve to death.

In 1952, first pupae were collected on August 20 in laboratory cages, although it is relatively certain that some appeared about the fifteenth of August. This stage required from twenty six to thirty one days for completion under laboratory conditions.

First moths appeared about the middle of September but the peak of the moth flight was not reached until the middle of October. Moths probably mate and lay eggs soon after their appearance. Numerous eggs appeared in jars containing moths as soon as five days after the moths emerged and possibly earlier. By the middle of November moths had practically disappeared.

The looper moths are probably chiefly nocturnal in their habits. They are occasionally seen in small numbers or in solitary flight during the day but they can be found in large numbers only during late afternoon or at night or when disturbed in their hiding places among the branches and leaves of trees and shrubbery. About dusk or shortly after on a warm fall evening when the moths are in flight they can sometimes be found in "swarms", the size of which depend upon the looper population. There is still another bit of evidence supporting the idea that looper moths are chiefly night fliers. During the flight period in the Naselle area, large numbers of moths fall into the streams and tide waters along the Naselle River. This occurs principally at night as evidenced by the relatively larger number of moths seen floating out on the ebbing morning tides. In other words, tides which go out in the early morning during the flight period carry large numbers of dead moths which fall into the water during the night while outgoing tides in the afternoon and evening are remarkably free from looper moths. It is probably because of the night activities of this insect that neither egg laying nor copulation was observed in the field during the past season.

Looper moths are relatively weak fliers and are seriously affected by wind and rain from which they seek protection. During heavy rains, they attach themselves to the lower side of leaves and branches and remain there unless disturbed. During heavy winds they seek sheltered spots and are more commonly found on the leeward or less

exposed sides of trees and foliage. When moths were disturbed along the edges of the tidelands during inclement weather they invariably attempted to escape by flying out into the open where they soon fluttered down into the grass from where many of them could not rise again. Many moths also fell into the water in this way and by watching them in flight it is easy to understand why so many of them fall into the streams and rivers and are carried out on the tides.

During the first two weeks of moth flight, warm dry weather prevailed and mating and egg laying were undisturbed by the weather. However by the time the peak of the moth flight was reached the fall rains had begun and these interfered seriously with the activities of the loopers. Rainfall for October at Naselle and Northhead was 7.48 and 5.58 inches respectively but most of this fell during the latter part of the month. November rains totaling almost 30 inches in the region certainly drowned out any remaining adult moths.

THE GRAYS HARBOR INFESTATION

In view of the heavy rains of October, 1931 during the flight period of the moths, the prediction had been made that looper activity would be very much diminished during the 1932 season. This view was further strengthened by spring and early summer examinations in Pacific and Grays Harbor Counties when eggs were found only in very limited numbers, whereas during the same period of the previous year

they were plentiful. However, after hatching had taken place, the loopers seemed to be so abundant in the known areas of infestation that it was decided that an accurate check should be made to determine where they were present in quantities sufficient to kill timber.

Following the meeting of the Forestry Committee of the Grays Harbor Chamber of Commerce on June 16, a survey of the hemlock looper infestation in Grays Harbor County was immediately started to determine what, if anything, should or could be done this year to avoid widespread and serious timber damage. Information was desired particularly as to the extent of the infested area, what portion of the area carried concentrated infestation capable of doing serious damage this year, what areas should be dusted, what was the present trend of the epidemic and whether control was practical and economic under existing conditions.

A general airplane reconnaissance of the forested area between Grays Harbor and the Naselle River was made by Keen and Beal on June 22, and the distribution of areas attacked last year was determined and sketched on a half-inch map. This air survey showed that the looper attacks of last season were confined to portions of Township 16 North, Ranges 8 and 9 West, and Township 17 North, Ranges 8 and 9 West, involving a total of about thirty sections or 20,000 acres. No infestation was found in Range 10 West nor was any found in Pacific County north of the Naselle area.

A more detailed ground cruise was then made of the known areas of infestation. During the last ten days in June the Land Office of the State of Washington furnished two men, Mr. Frank Neeley and his son who aided materially in this work. Mr. F. L. Nethery of the Weyerhaeuser Timber Company also gave valuable aid and information. The number of loopers that it was possible to collect in a five minute period in any locality served as a rough index to their abundance. These collections showed that loopers were very generally distributed throughout the entire area, even in places where defoliation was not evident, but that they were the heaviest in zones surrounding the spot-killings of last year. Some of the heaviest collections were made in the vicinity of the frames where feeding tests were being made.

From both the air and ground surveys, it was determined that the spot-killings were liberally sprinkled throughout the entire area. Thus any dusting program could not be concentrated only on the spots of evident previous damage, but would have to take in an entire basin or topographic unit, with the consequent dusting of both heavy and light infestations.

Unlike the Naselle area there are no large blocs of dead timber in the Grays Harbor outbreak. Instead the affected timber lies peppered throughout an area including some twenty sections in extent. Some of the ravines show streaks of gray dead timber which thin out to scattered individual trees on the higher spots.

The density of looper concentration was determined by means of muslin frames (Fig. 8) stretched beneath the trees to catch the droppings—a method found last year to give a very reliable index of the number of loopers present. Five-minute collections of loopers were made near the frames in order to furnish a basis for tying in the widespread collections to those in areas of known looper population. During the first week collections were made from the frames on alternate days and feeding tests were run with three sets of 200 loopers confined in glass jars. The relative amount of droppings in the jars and on the frames in any given time served as an index to the number of loopers present in the foliage over any frame. These feeding tests indicated that over frames showing the heaviest feeding there were only about 600 loopers. In contrast to this, the 1931 records on the Naselle area showed that at least 2000 loopers over a single frame (10 square feet) were necessary to bring about defoliation of killing severity, and some frames ran over 4000 loopers. In other words, the 1932 infestation was found to be much less severe than that of the previous year, and even in the heaviest centers the loopers were not concentrated enough to do any serious damage.

Thus the early records of this year tended to confirm the predictions made last year that the outbreak for this year would be more widespread but less acute; and that as a consequence airplane dusting would be of considerable less urgency and at the same time much more

expensive than the operation of last year which was carried out on a relatively concentrated area, and where losses without control would have been extremely heavy. On the basis of the results of the early records of 1932, dusting against the looper in the Grays Harbor region was not recommended by the Bureau. The instigation of a $60,000 control project of airplane dusting was rapidly gaining support, however, this was called off, and a heavy expense to the timberland owners and the state was averted through the recommendations of the Bureau.

Feeding tests were continued throughout the remainder of the summer. Six hundred looper larvae were collected each week, caged in the laboratory in three groups and fed, and the droppings over a twenty-four-hour period collected and measured in order to determine the amount of feeding of a known number of larvae as well as to furnish a basis for estimating the number of larvae present over the frames.

These feeding experiments showed that the amount of droppings from a known number of looper larvae increased with the size of the larvae (graph II). Temperatures were more nearly uniform in the laboratory and the loopers were less affected by external influences than they were under field conditions. These tests were discontinued at the end of August when feeding in the field had been reduced to a minimum.

Similarly droppings were collected from eight outdoor frames (10 sq. ft. in size) (Fig. 3) and measured to determine the number of loopers over each area. The results from three typical frames are presented in graph III. Here as in the laboratory, feeding increased as the loopers grew in size and was also directly affected by temperature. The decreases in amount of droppings, notably August 2 (graph III) correspond with low average temperatures. During warmer days the larvae feed more heavily. Rain apparently had little or no effect upon the larval feeding. They fed continuously during rainy periods as well as during dry days. The peak of outdoor feeding was reached by about the middle of August after which it decreased rapidly until early September when it practically ceased.

The results of these tests confirmed those of earlier tests, namely, that loopers were not numerous enough to do any serious damage to the timber.

A dozen frames were also located in the looper area in the Naselle region in Pacific County to obtain further information on the amount and distribution of feeding. Only occasional examinations were made on these frames during the summer; however, before records were taken the frames were cleaned and all collections were made over a twenty four hour period. These records indicated that over a few of the frames feeding was considerably heavier than that found in the Grays Harbor infestation but here too feeding was light enough

so that little further damage resulted from the loopers this year. In a few centers of infestation, additional defoliation occurred and a few small new infested spots appeared, but there was no apparent extension of the general area of infestation.

Late in August after looper feeding had practically ceased another airplane reconnaissance was made of the looper infestation near Grays Harbor. It was gratifying to see that in agreement with the ground work, the feeding tests, and observations on the activity of the larvae, there had been little or no extension of the infested areas this year. A small amount of red foliage showed up on the borders of some of the infested patches of hemlock but was so rare as to be insignificant. On the whole the area appeared greener than it did in the early summer.

OBSERVATIONS UPON THE INSTARS OF LOOPER CATERPILLARS

A large number of larvae of the hemlock looper were collected at regular intervals throughout the summer, preserved and subsequently measured for the purpose of determining the number of larval instars and the per cent of larvae in each instar at all times. Because of the consistent grouping of the head measurements only 834 of these larvae were used for this purpose. Head widths were measured by the use of a binocular microscope and micrometer. This instrument was accurate to 0.01 m.m. Body lengths were measured by a m.m. rule.

The number of instars was found to be five. However, it is not known whether some of the larvae pupate during the fourth instar or whether others pass through more than five moults. Measurements of the larvae indicate that there are five very distinct and separate sizes (Fig. 4) and it is assumed that each of these represents an instar.

Description of Larval Instars

1st Instar - When first hatched the larvae have dark brown to black heads from .36 to .47 m.m. in width. The bodies are distinctly marked by alternating dark and light gray bands. In length they measure about 5 m.m.

2nd Instar - After the first molt the heads are still distinctly dark in color and the widths are increased to from .58 to .76 m.m. and the body length increases to about 7 m.m. The body markings which characterize the first instar while still visible are much less distinct.

3rd Instar - In the third instar head widths measure from .89 to 1.18 m.m. and the head loses its dark color becoming mottled with brown and gray. The dark bands on the body appear only as dark spots showing principally on the sides of the larvae. In length the body measures about 13 m.m.

4th Instar - During the fourth instar head size increases to from 1.29 to 1.76 m.m. and in color the heads blend very well with the body color. Body length increases to between 15 and 20 m.m. and body markings become less uniform with wide variations of gray and brown predominating.

5th Instar - Head widths in the fifth instar vary from 1.91 to 2.56 m.m. and head color very closely resembles body color. Body length measures from 20 to 30 m.m. Body markings are variable and color patterns are not at all uniform.

The size, body length and color of the larvae are extremely variable in all instars. The width of head is the one character which is relatively constant for each stage and which can be relied upon to distinguish the five instars. Even this falls down occasionally, the extreme of one instar being indistinguishable from the opposite extreme of the preceding or succeeding stage. On normal individuals the larval stages can easily be determined with the naked eye after a little practice.

The frequency of occurrence of certain head widths of all larvae measured and the spread in head measurements in each instar is illistrated in graph IV. A high per cent of the head measurements taken on first instar larvae were of one size and the spread between the extremes of this instar was only .11 m.m. Similarly a majority of head measurements of the second instar grouped very closely but the spread between the two extremes increased to .18 m.m. No such concentration of head widths was found during the third instar and the difference in head measurements in this group increased to .29 m.m. Both the fourth and fifth instar measurements continue the tendency to spread the groups out over a wider range and greatest

differences in them are represented by .47 m.m. and .85 m.m. respectively. It should be stated that the number of larvae represented in each instar is not the same. Enough larvae were measured to obtain the range in sizes in each instar. However, if a similar number had been used in each case more uniformity in the height of curves in graph IV would naturally be expected.

In an article written by Dr. Dyer[2] a number of years ago, he mentions the fact that a certain ratio exists between the head widths of the different instars. For instance, if one has the head measurements for two consecutive instars, the head widths of all instars can be calculated approximately. This holds true in the case of hemlock looper larvae. The ratio between the first and second instars is 66 and is practically the same between the second and third, third and fourth, and the fourth and fifth instars also.

Looper larvae collected on known dates were grouped according to instars in order to determine the per cent of them in each instar at any given time. This information is specifically presented in graph IV and in more general terms in table 1.

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[2]Dyar, H. G. Psyche. Vol. 5, pp 420-422. 1890

Table 1 - Per cent of hemlock looper larvae in the different instars according to dates in 1932

Instar	Head width in m.m.	Spread in m.m.	June 17	June 27	July 7	July 16	July 23	Aug 3	Aug 23	Sept 1
1st	.36- .47	.11	47	16	7	0	0	0	0	0
2nd	.58- .76	.18	51	79	59	11	5	0	0	0
3rd	.89-1.18	.29	2	5	34	77	18	1	0	0
4th	1.29-1.76	.47	0	0	0	12	71	38	12	0
5th	1.91-2.36	.65	0	0	0	0	6	61	88	100

It will be noted from table 1 that on June 17 the date of first collection of larvae more than fifty per cent of them were already in the second instar and a few had reached the third instar. This indicates that first larvae appeared a considerable time previous to the first date of collection. The progress of larval development is shown in the increasing number of insects that go into the later instars as the summer progresses. By the middle of July no more first instar larvae could be found. By early August no further second instar larvae were collected and by the end of the month third instar larvae had also disappeared. The early September collection resulted only in mature larvae from the fifth instar. Measurements on larvae collected after September 1st showed them to belong to the 5th instar.

DUSTING EXPERIMENTS

A few dusting experiments were made during the summer in order to determine the adhesive quality and the effectiveness of various dusts against the looper larvae. At the time these tests were made the larvae were about two thirds grown (4th and 5th instars) (early August) and a maximum dosage of poison was necessary to kill them. Six cages were set up with small potted hemlock trees in them and 200 larvae placed on the foliage in each cage (Fig. 5). One cage was left undusted as a check and the other five were heavily but evenly dusted with five different poison dusts. After the trees were dusted there was a general exodus of larvae from the dusted foliage to the side of the cages and it is believed that had any fresh foliage been available a minimum amount of feeding would have occurred on the dusted foliage. At the end of the first day most of the larvae had left the foliage and remained on the sides of the cages. They were again collected and put back on the dusted foliage. They were examined daily and at the end of the first, third, fourth, and fifth days, counts of dead larvae were made in each cage. The results of these counts are shown in the following table II.

Table II - Mortality resulting from dusting of hemlock looper

Materials	Larvae	24 hrs.	72 hrs.	96 hrs.	120 hrs.
Flu-si dust	200	9 dead	193 dead	197 dead	197 dead
Arsenate of lead (Dow)	200	5 "	185 "	191 "	192 "
Calcium arsenate (Acme)	200	4 "	182 "	188 "	198 "
Arsenate of lead (Acme)	200	8 "	182 "	185 "	198 "
Calcium arsenate (Niagara)	200	12 "	190 "	193 "	196 "
Check	200	25 "	73 "	84 "	102 "

During the first day almost no mortality was noted. This was no doubt due to the fact that many of them left the foliage during this time. On the second day they began dying slowly and by the end of three days mortality was heavy. Dusting was so heavy in all cases that a good kill was obtained in all dusted cages. The heavy mortality in the check cage is believed to be the result of the wilt disease which made its appearance about this time. Because larvae were nearly mature and extremely difficult to collect in sufficiently large numbers, no further dusting experiments were attempted.

LOOPER PARASITES AND PREDATORS

During the year an attempt was made to obtain further information on looper parasites and predators, especially to learn something of their life history, habits and effectiveness in keeping down the number of loopers. Ground cages (Fig. 6) were installed in the early

spring of 1932 and overwintering dipterous puparia, believed to be parasitic on the looper, were caged in the soil under natural field conditions to determine time of emergence. Observations in the field, actual counts on per cent of loopers parasitized and cage records yielded some further information on looper parasites.

By far the most abundant parasite of the looper larvae was a dipteran *Winthemia occidentis* (Rein), whose size and general appearance closely resembles an ordinary house fly. The underground puparia transform to adult flies in midsummer and after mating, the females lay their eggs on the nearly mature looper larvae. In 1932 the cage records showed that 10 per cent of the flies emerged before July 6, about 85 per cent emerged between that date and July 30, and only 5 per cent emerged after the end of July. Adult flies were especially numerous during the month of August. First eggs of this parasite were observed early in August. By actual count of parasitized looper larvae in an infested area in Greys Harbor region, it was found that on August 12, 25 per cent showed one or more eggs of this dipterous parasite. By August 22 parasiticism by this insect alone had increased to 38 per cent and by September 2, it had risen to 54 per cent. Parasiticism by this insect was less in the Naselle area.

Table III - Per cent looper parasiticism by (Winthemia occidentis)

Date	Number of looper larvae	Per cent parasiticism Pacific County	Per cent parasiticism Grays Harbor County
Aug. 12	200	—	25.0
Aug. 22	500	—	39.0
Aug. 27	950	31.0	- -
Sept. 2	320	—	54.0
Sept. 12	950	16.0	- -
Sept. 18	730	14.0	- -

On the second of September ten of the adult flies were caged with fifty unparasitized looper larvae and closely observed in order to check their egg laying habits. The flies went to work at once and at the end of the first hour at least half of the looper larvae had eggs of the fly upon them. Some had as many as five eggs. At the end of the first day most of the larvae carried eggs, the majority with two or three eggs on them. The distribution of these parasite eggs under field conditions was more general for larvae collected out of doors only occasionally carried two of the eggs of this parasite and rarely were three eggs found on one larva.

In laying an egg the female fly approaches the looper cautiously and placing her anterior pair of legs against the body of the looper (usually close behind the head), she bends the tip of the abdomen down and under her body and thrusts it quickly forward in a telescoping process thus depositing the egg neatly and rapidly on the side of the looper. This is all done with very little disturbance to the loopers,

and they do not fight off the flies nearly so vigorously as they do some of the hymenopterous parasites which insert their eggs in the bodies of the loopers.

The fly eggs are white in color, elliptical, flat next to the loopers and glued so tightly to them that it is nearly impossible to remove the eggs without injuring the larvae (Fig. 7).

Another dipterous parasite Madremyia saundersii (Will) similar in appearance to the above fly was reared from looper larvae in very small numbers. However comparatively few of these appeared to be present in the field. They emerged from parasiticised larvae in the laboratory late in September. At least some of them must overwinter in the adult stage.

Three hymenopterous parasites generally collected were definitely established as parasitic on the looper larvae. Amblyteles cestus (Cress) was the most common one found. It could be seen during the summer months searching among the twigs and branches of looper infested trees. While it was not observed in the process of depositing its eggs on the loopers a few adults were reared from caged looper larvae, thus definitely establishing its identity as a parasite. They emerged from parasiticised larvae late in September. In late summer and fall the adults of this species were collected in large numbers in the grass, moss and small spruce trees along the tidelands where looper adults were commonly found.

Another similar hymenopterous species Amblyteles puerilis (Cress) also believed to be parasitic was commonly found in large numbers associated with the above parasite although we were unable to rear this insect from looper larvae.

A third hymenopterous parasite Amblyteles sp was collected in very small numbers and two of this species were reared from looper larvae. They emerged late in September.

A fourth hymenopterous species (Hopk. No. 18828c as yet unidentified), a small wasp-like little insect was seen on numerous occasions depositing its eggs in looper larvae. It always approached the larvae from the rear climbed on their backs and inserted their eggs through larval punctures. Loopers fought these parasites viciously, probably because of the punctures made in egg laying. None of these parasites were successfully reared although several parasitized larvae were caged.

A number of other hymenopterous insects mostly of small size were collected at random among the looper infested branches although none of them were definitely established as looper parasites.

A few secondary hymenopterous parasites were reared from primary dipterous parasites although they have not yet been identified.

A very important predator Scaphinotus angusticollis var nigripennis (Roesch), a large black ground beetle, was commonly found feeding on loopers during various life stages. These beetles were observed searching out larvae, prepupal larvae, and pupae of the looper

and killing and devouring them. The beetles are numerous enough to be an important enemy of the looper.

In general parasites of the looper were found to be very numerous. By early September over 50 per cent of the larvae were parasitized by a single dipterous parasite and it is estimated that additional parasitism in the areas studied would bring this figure up to about 75 per cent. The effect of the wilt disease so interfered with other controlling agencies that the relative importance of each could not be accurately measured.

DISEASE

About the middle of August when most of the looper larvae were in the fourth and fifth instars, a disease appeared among them which seriously affected both those in the cages and those in the field. A number of infected specimens were collected and forwarded to the Gipsy Moth Laboratory at Melrose Highlands in the hope that a determination of the disease might be possible, however the material was not received in very good condition and no identification was made. The diseased larvae were quite characteristic in appearance (Fig. 8). The bodies of the dead larvae remained attached to the leaf or branch on which they died. More often the legs remained clinging to the stems while the remainder of the body hung limply downward. In this position the bodies quickly wilted and dried out and often remained on the trees for a long time, usually until the wind and rain removed them. For want of a better term the disease is hereafter referred to as the "wilt disease".

During the late summer and fall of 1932 "the wilt disease" was so prevalent that it seriously interfered with the results from the parasite rearing cages. Many parasitized looper larvae which had been caged for history records of the parasites were lost through the work of this disease. It was very common in the field but when larvae were collected and brought into the laboratory and placed in jars with cloth or screen tops, it became extremely active and in many cases the larvae were able to survive for only a few days.

The following table shows the per cent of larvae which died of disease during some of the caging experiments.

Table IV - Effect of disease on looper larvae

Number of larvae	Number of days to final examination	Number of parasites survived	Number of moths emerged	Per cent of larvae killed by disease
36	30	0	0	100
50	19	6	0	88
50	35	7	2	82
50	30	6	0	88
50	14	5	3	84
100	30	1	6	93
100	30	1	0	99
100	21	0	0	100
100	30	3	0	97
840*	34	0	1	99+
840*	34	1	1	99+
		Weighted average:		99.4

*Outdoor cages

It should be mentioned here that heavy larval mortality was apparent in the jars after two or three days and that by the end of the first week in many cases, few or no living larvae could be found. Over 99 per cent of all caged larvae died of this disease. It was apparent that caging or grouping of large numbers of larvae whether in the laboratory or out of doors resulted in increased mortality by this so-called "wilt disease". A small per cent died in the field, but here too, mortality was extremely heavy and it is estimated that possibly 75 per cent of the larvae present when this disease made its appearance died as a result of it.

The disease undoubtedly had a very beneficial effect upon reducing the number of larvae. In fact it was the most important single factor affecting them. It affected parasitized and non-parasitized larvae alike and because of this trait greatly reduced the number of emerging parasites as well as the number of loopers.

EFFECT OF DEFOLIATION BY LOOPERS

Plots which were established in the Moselle outbreak in 1931 to determine the amount of looper defoliation required to kill timber were reexamined again this year in May and again in November. The per cent of defoliation was estimated when these plots were established.

In a number of cases during last years examination, where the crown still showed a few green needles and the cambium was still fresh, the trees were put in the questionable class since it was then uncertain whether they might live or die. Wherever Ambrosia

beetles had entered the wood the tree was classed as dead, since these beetles select only dead or dying sapwood for their activities. Table V shows comparative results of 1931 and 1932 examinations.

Table V - Comparative results of 1931 and 1932 examinations

Per cent of defoliation	Trees still alive 1931	Trees still alive 1932	Recovery uncertain 1931	Recovery uncertain 1932	Trees dead 1931	Trees dead 1932	Per cent Trees dead 1931	Per cent Trees dead 1932
0 - 50%	17	17	3	0	0	3	0%	15%
51 - 75%	1	3	10	0	0	8	0%	72%
76 -100%	1	2	25	0	30	54	54%	96%

The chief difference between this year's and last year's record of the above plot is that all of the trees which were listed under "recovery uncertain" have either definitely moved on into the dead group or have entirely recovered. Of this original group of 38 doubtful trees, 3 recovered and 35 died. Final figures on effect of defoliation show that 15 per cent of the trees died where 50 per cent or less of the foliage had been removed, that 72 per cent of them died where defoliation was from 51-75 per cent and that 96 per cent, practically all of them, died where 76-100 per cent of the foliage had been removed.

POSSIBILITY OF SALVAGE IN KILLED HEMLOCK

There was some belief that there might be a possibility of salvage of the hemlock killed by the defoliation of the hemlock looper. With this in mind two one-acre plots were established in the center of the infested area and the individual trees marked, numbered and tallied. They were examined for insect attack in May and again in November. Attack by Ambrosia beetles is sufficient to exclude

the hemlock from the market. Pulp mills will not accept trees showing Ambrosia beetle damage and logs thus damaged are heavily docked by the other mills as well. All trees within the boundaries of the one-acre plots were tallied whether living or dead. Table VI shows the results of the examinations of two plots examined for Ambrosia beetle defect.

Table VI - Attack by Ambrosia beetles

Plot	None	Light	Moderate	Heavy	Per cent damaged
1	20	22	25	31	80.0
2	21	4	21	41	76.0
Total	41	26	46	72	
Per cent total	22	14	25	39	78

It will be seen from the above table that 78 per cent of the trees examined during 1932 showed attack by Ambrosia beetles. The 22 per cent which showed no attack were largely green living trees which had not been very seriously affected and had thereby successfully weathered the looper attack. Practically every tree which had been killed by the defoliation was found to contain evidence of attack by Ambrosia beetles, and in by far the majority of cases the attack was moderate to heavy. Attack by the pin hole borers was found to increase materially during the summer of 1932. Between May and November of this year the attack extended from

about 60 per cent to practically 100 per cent of the dead trees. At the time of the November examination a large number of limbs already showed the effects of decay. They had fallen off the trees and fairly littered the ground with their presence. In a few cases even the tops had begun to break out of some of the hemlock. Salvage of any of the hemlock at any future date is entirely out of the question. It is too badly affected by insects and decay to have any salvage value.

Spruce was less seriously affected and where it is heavy enough may be salvaged at any time prior to the introduction of fire into the area which is likely to occur during the first real dry period.

SUMMARY

During the summer of 1932 the activities of the hemlock looper were followed in a recent outbreak in the Grays Harbor region and in a somewhat older outbreak in the Naselle area in Pacific County in Washington.

The infested areas in Grays Harbor County were located by means of an airplane reconnaissance and subsequently examined by a ground crew. Early larval counts and feeding records indicated that the larvae were not abundant enough to defoliate and kill any large amount of timber. About 800 larvae over frames covering 10 square feet were the most abundant found, whereas last year's records showed that 2000 or more larvae were necessary over plots of this size to result in killing of the trees.

On the basis of these records, control by airplane dusting was strongly advised against by the Bureau and some $60,000 was saved the private timber owners and the State.

During the summer a small looper outbreak covering about 100 acres in extent was examined on the Snoqualmie National Forest near Darrington, Washington. This outbreak was at an elevation of 1200 to 1500 feet on the western slopes of the Cascades and far removed from the fog belt type in which loopers have heretofore been confined. A few moths were also found flying in the vicinity of Quinault and Crescent Lakes, a considerable distance north of the present outbreak.

Eggs of the loopers begin hatching early in May and continue through until about the middle of June. Larvae are present from early May to the middle of September. The larvae pass through five distinct instars during their development. The ratio between head widths of different instars was found to correspond to Dyar's ratio, i.e., a definite ratio exists between the head measurements of any two successive instars. The ratio for the hemlock looper was determined as about 66.

Pupation begins about the middle of August and the insects remain in this stage from 26 to 31 days. By the middle of October, pupae could no longer by found.

First moths appear about the middle of September but the peak of the moth flight is not reached until the middle of October. By the middle of November most of the moths have disappeared. Egg lay-

ing occurs during the flight period but probably shortly after the emergence of the individual female moths.

Dusting experiments indicated that there was a strong tendency of the looper larvae to leave the dusted foliage shortly after the application of the dust. No very great difference in either adhesive qualities or lethal qualities of the five dusts tested was noted.

Parasites were found to be very abundant and parasiticism, especially in the larval stage, was high. The life history and habits of Winthemia occidentis (Rein) the most abundant dipterous parasite were partially determined. They overwinter in the ground as mature larvae in small cocoons, emerge principally in July, and lay eggs on the looper larvae in August. Parasiticism by this insect alone was found to be as high as 50 per cent.

Other insects definitely established as parasites during the past season were Madremyia saundersii (Will), Amblyteles cestus (Cress), Amblyteles sp., a small hymenopterous parasite (yet unidentified) and Scaphinotus angusticollis var nigripennis (Roesch) a very important predacious beetle. Parasiticism is estimated during the season at about 75 per cent of the total larvae.

A very destructive "wilt disease" attacked the looper larvae from about the middle of August to the end of the summer killing countless numbers of them. No determination of this disease has yet been made. It resulted in the death of over 99 per cent of all caged larvae regardless of whether these were caged in the laboratory or in

the open. It is estimated that this disease killed at least 75 per cent of all the larvae on the infested area.

Reexamination of plots marked in 1931 showed that, of the trees with 0-50 per cent defoliation, 15 per cent died, that of those showing 51-75 per cent defoliation, 72 per cent died, and that of those with 76-100 per cent defoliation, 96 per cent died.

Ambrosia beetle damage increased during the summer to include practically all trees killed by the loopers. Insect damage and serious decay in the hemlock trees eliminates the possibility of salvage of this material.

Damage by the hemlock looper in the Grays Harbor region during 1932 was so limited as to be almost negligible. No further killing of trees occurred and additional defoliation was not heavy enough to attract attention. From the air the timber appeared as green as it had during the early summer.

Very little additional looper damage occurred in the Naselle outbreak. In some centers of infestation, further defoliation was noticeable. Also a few small spots showed up within the old boundaries of the previous outbreak. Comparatively speaking, losses through defoliation by the hemlock looper in 1932 were insignificant. In both the Grays Harbor and Naselle areas the heavy concentration of loopers is undoubtedly over and little or no further damage is anticipated from either of these infestations in the immediate future.

Fig. 1 - Typical spruce hemlock type showing rank undergrowth.

Fig. 2 - Young hemlock stand showing density of timber.

Fig. 3 - Muslin frame of type used to collect looper droppings.

Fig. 4 - Larval instars of hemlock looper. Reading left to right, 1st, 2nd, 3rd, 4th, and 5th respectively.

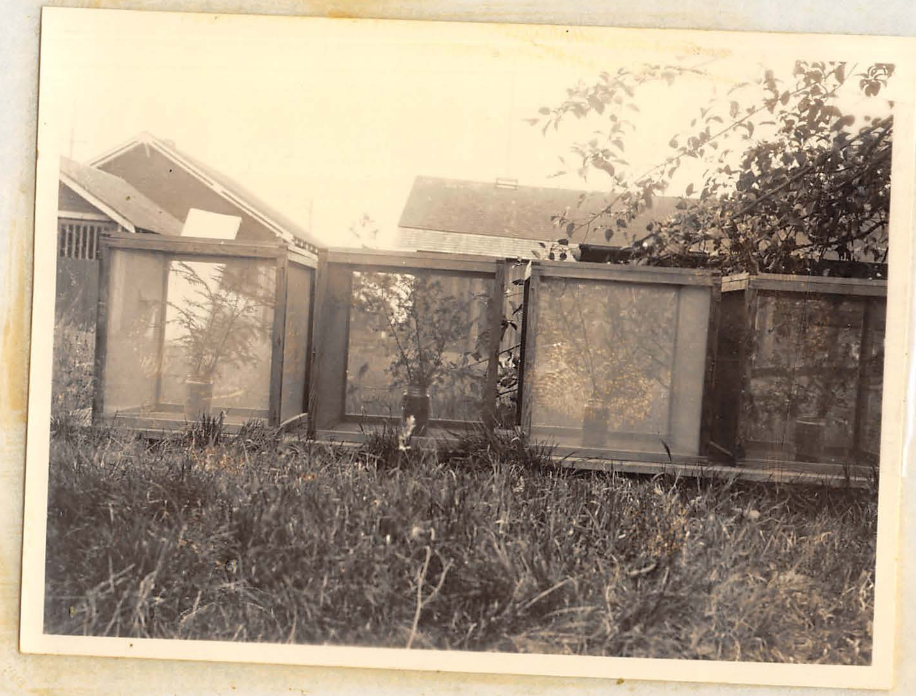


Fig. 5 - Cages used for dusting experiments. Note small potted hemlock trees in cages.

Fig. 6 - Type of outdoor cage used for rearing looper parasites.

Fig. 7 - Dead hemlock looper larvae showing parasite eggs attached to them.

Fig. 8 - Wilted looper larvae dead as a result of disease.

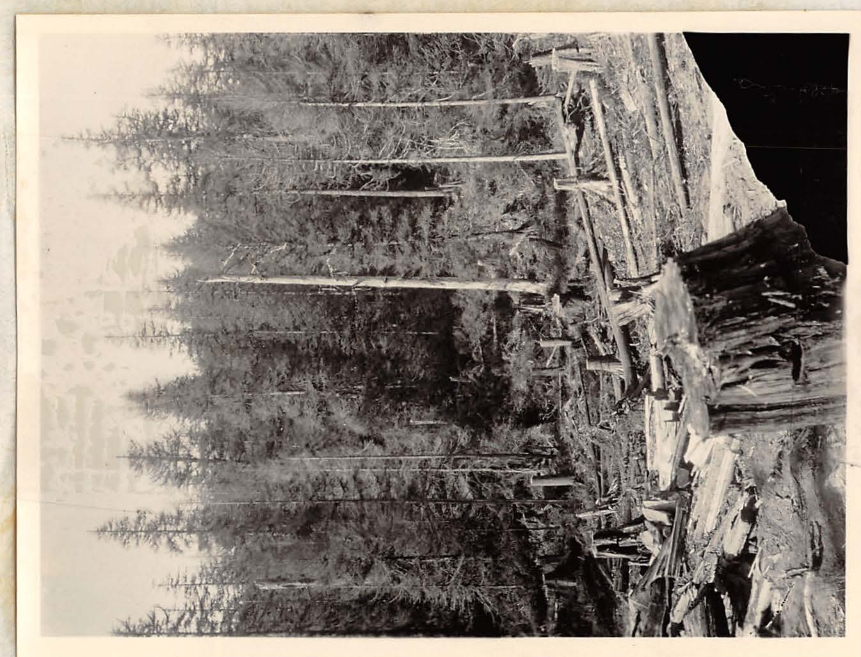
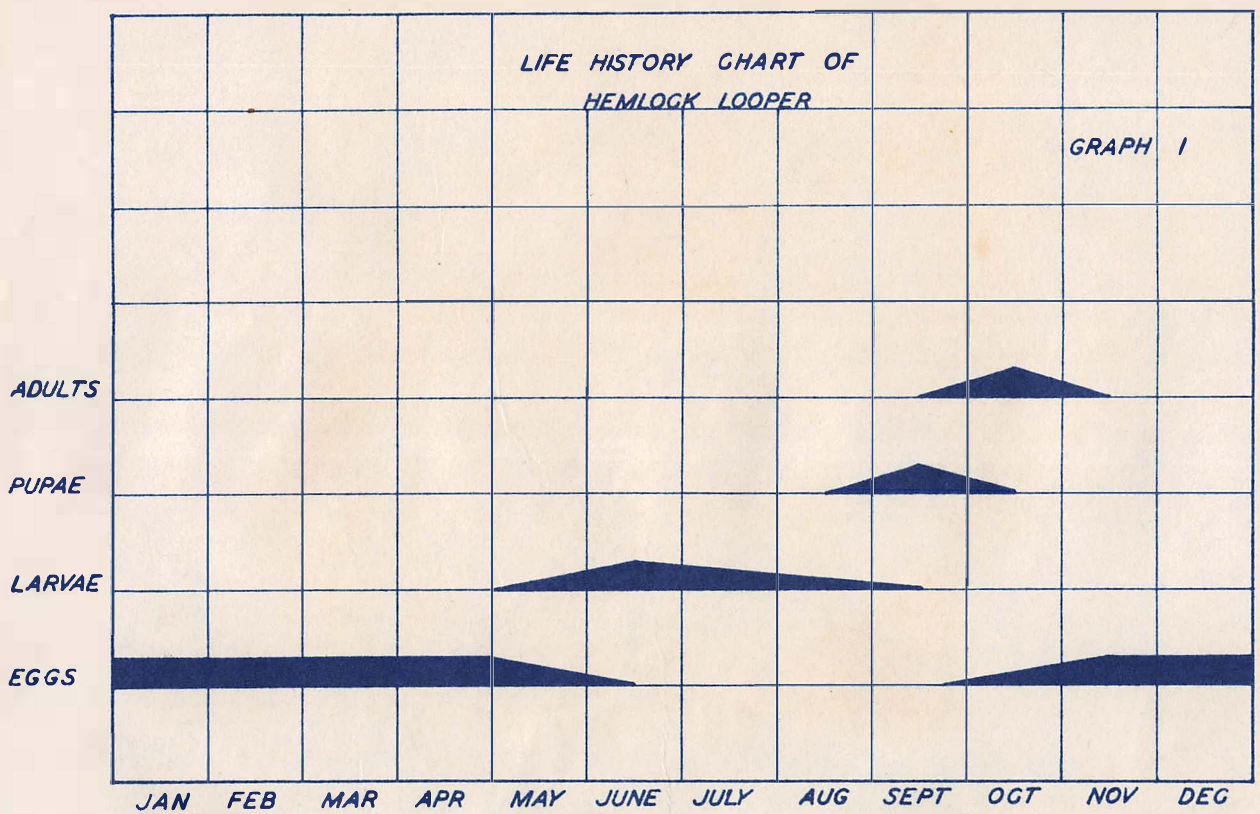
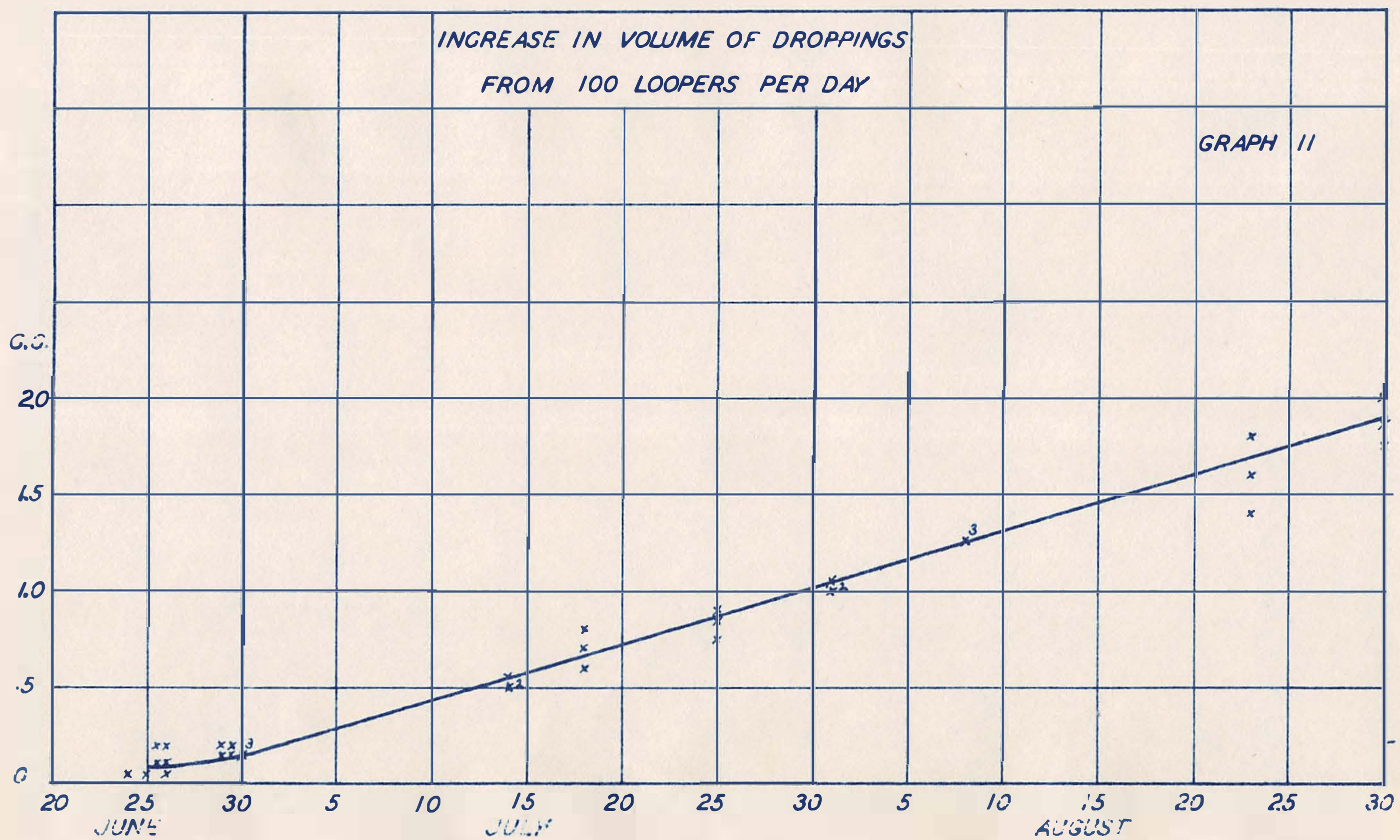
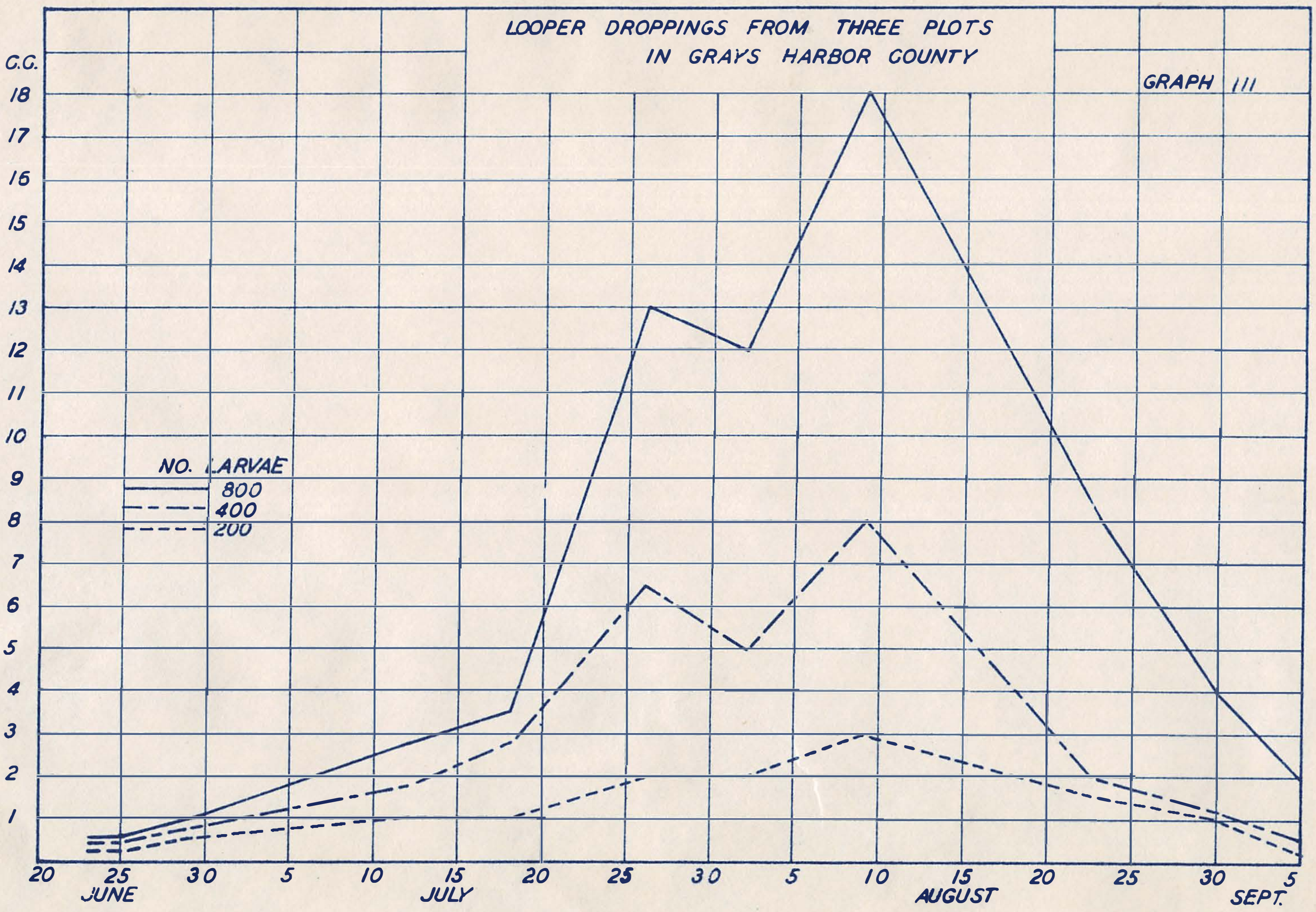
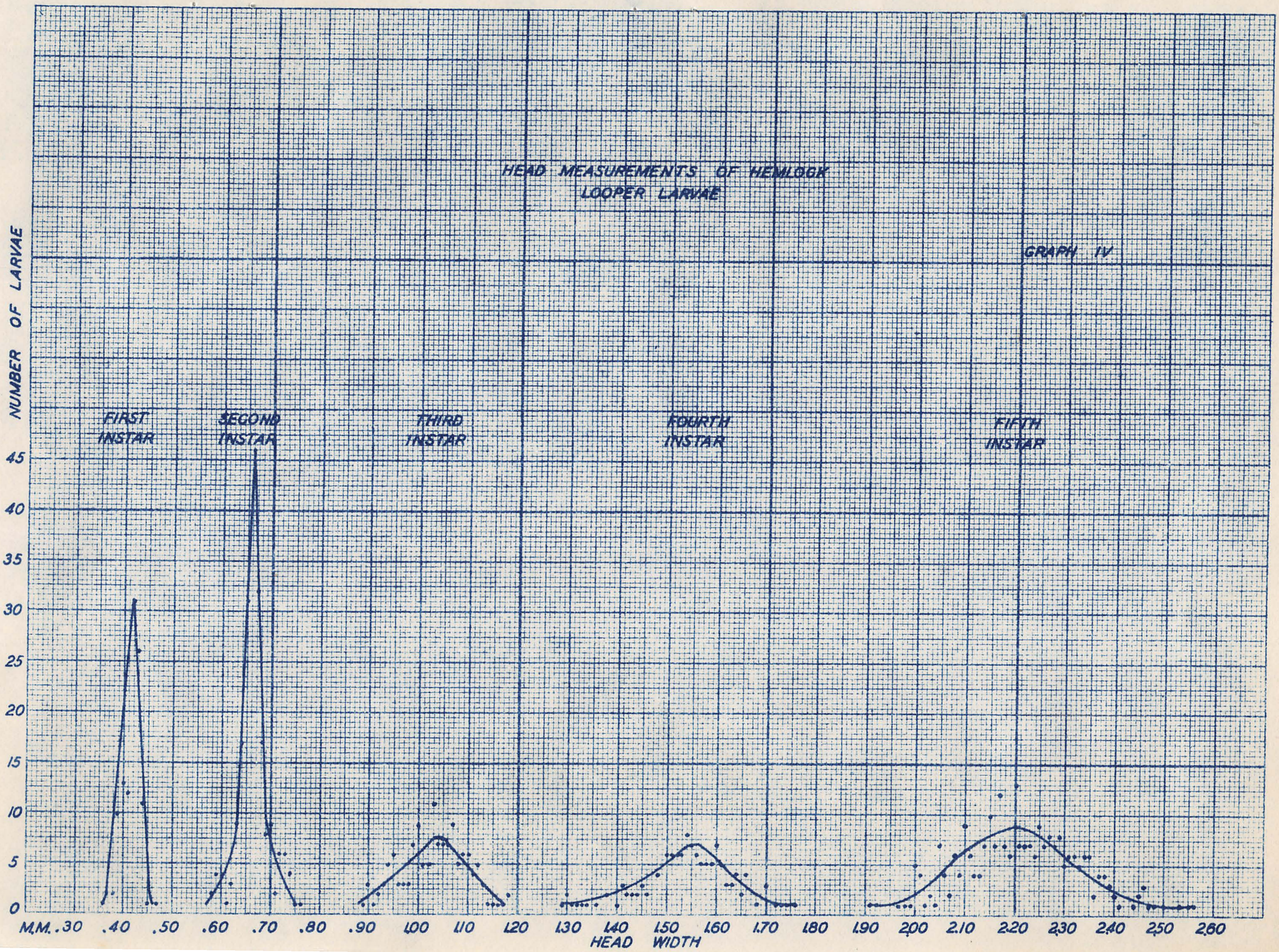


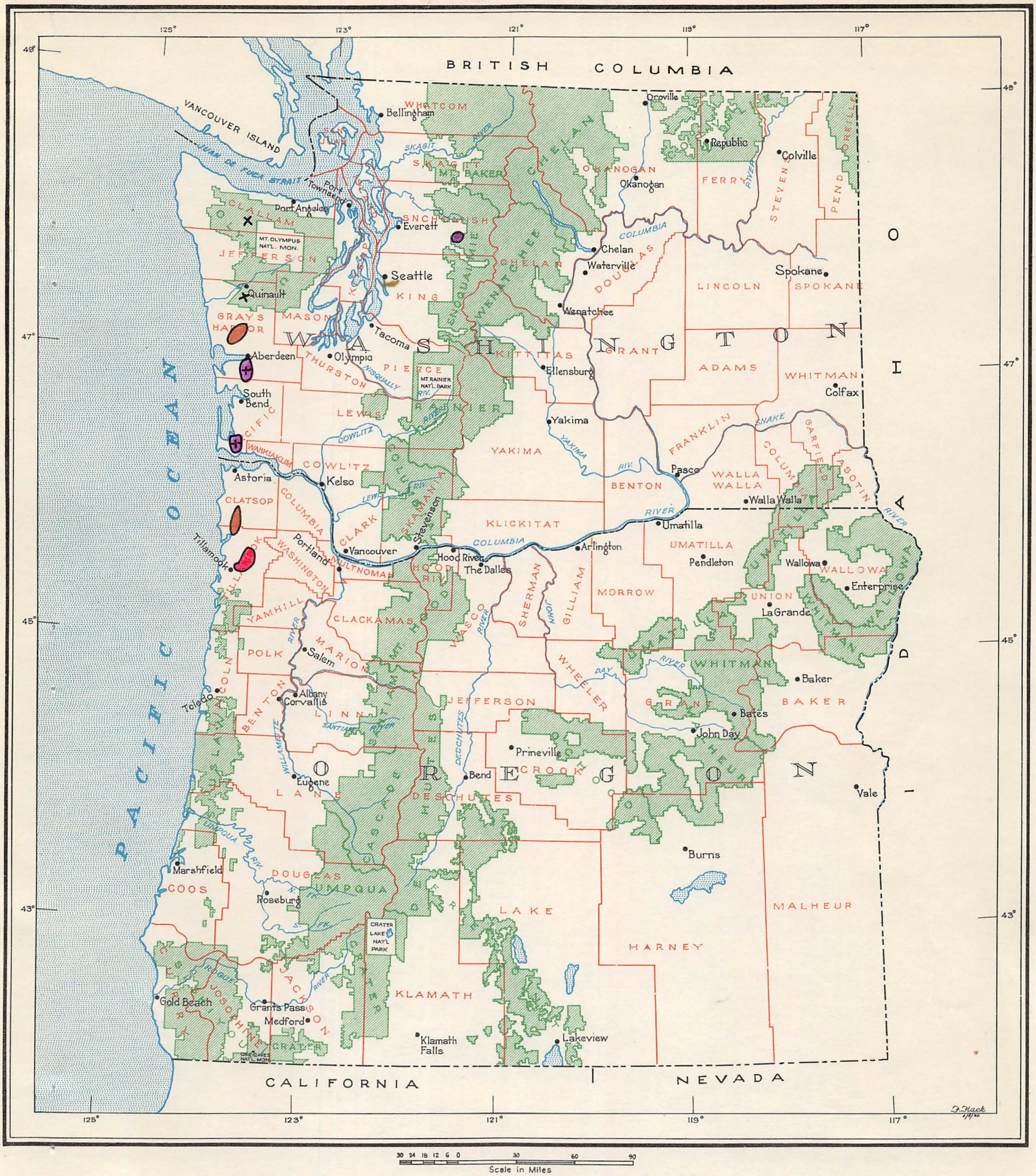
Fig. 9 - Dead hemlock killed by hemlock looper


LIFE HISTORY CHART OF
HEMLOCK LOOPER
GRAPH I
ADULTS
PUPAE
LARVAE
EGGS
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC


INCREASE IN VOLUME OF DROPPINGS
FROM 100 LOOPERS PER DAY
GRAPH 11
C.C.
2.0
1.5
1.0
.5
0
20
25
30
5
10
15
20
25
30
5
10
15
20
25
30
JUNE
JULY
AUGUST


LOOPER DROPPINGS FROM THREE PLOTS
IN GRAYS HARBOR COUNTY
GRAPH III
C.C.
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
NO. LARVAE
800
400
200
20
25
JUNE
30
5
10
15
JULY
20
25
30
5
10
15
AUGUST
20
25
30
5
SEPT.


HEAD MEASUREMENTS OF HEMLOCK
LOOPER LARVAE
GRAPH IV
NUMBER OF LARVAE
FIRST INSTAR
SECOND INSTAR
THIRD INSTAR
FOURTH INSTAR
FIFTH INSTAR
45
40
35
30
25
20
15
10
5
0
M.M. .30 .40 .50 .60 .70 .80 .90 1.00 1.10 1.20 1.30 1.40 1.50 1.60 1.70 1.80 1.90 2.00 2.10 2.20 2.30 2.40 2.50 2.60
HEAD WIDTH



LEGEND

- State Lines
- National Forests
- County boundaries

PACIFIC NORTHWEST FOREST EXPERIMENT STATION

Project Hemlock Looper Outbreaks in the Pacific Northwest

- Recent Outbreaks 1928-1932
- Tillimook Outbreak 1921
- Grays Harbor and Clatsop County Outbreaks 1890
- × Moths in flight 1932